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5876836 INSPEC Abstract Number: B9805-7260-012
Title: **The application of poly(phenylene) type polymers and oligomers in electroluminescent color displays**
Author(s): Tasch, S.; Brandstatter, C.; Graupner, W.; Hampel, S.; Hochfilzer, C.; List, J.W.E.; Meghdadi, F.; Leising, G.; Schlichting, P.; Rohr, U.; Geerts, Y.; Scherf, U.; Mullen, K.
Author Affiliation: Inst. fur Festkorperphys., Tech. Univ. Graz, Austria
Conference Title: Flat Panel Display Materials III. Symposium p.325-30
Editor(s): Fulks, R.T.; Parsons, G.N.; Slobodin, D.E.; Yuzuriha, T.H.
Publisher: Mater. Res. Soc, Pittsburgh, PA, USA
Publication Date: 1997 Country of Publication: USA xi+338 pp.
ISBN: 1 55899 375 4 Material Identity Number: XX97-02853
Conference Title: Flat Panel Display Materials III. Symposium
Conference Date: 31 March-3 April 1997 Conference Location: San Francisco, CA, USA
Language: English
Subfile: B

...Abstract: the oligomer hexaphenyl, are very suitable materials for realisation of efficient, stable, large area blue **organic light emitting diodes** (OLEDs). The emission of blue OLEDs can be efficiently converted into all other emission colours...

... EL device is covered with highly fluorescent dye/matrix layers, which are excited by the **blue** emission and emit **lower** energy photoluminescent light. Secondly, a new method for producing **efficient white** light emitting polymer diodes (e.g. for backlight sources in liquid crystal displays) based on...
...Identifiers: **organic light emitting diodes** ; ...

... **OLED** efficiency...

... **OLED** stability...

...blue **OLED** emission conversion

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11/3,K/6 (Item 6 from file: 2)
DIALOG(R)File 2:INSPEC

5696373 INSPEC Abstract Number: B9710-4260D-037
Title: **White and unsaturated color organic light emitting diodes**
Author(s): Dodabalapur, A.; Strukelj, M.; Jordan, R.H.; Rothberg, L.J.; Miller, T.M.
Author Affiliation: AT&T Bell Labs., Murray Hill, NJ, USA
Conference Title: Electrical, Optical, and Magnetic Properties of Organic Solid State Materials III. Symposium p.59-63
Editor(s): Jen, A.K.-Y.; Lee, C.Y.-C.; Dalton, L.R.; Rubner, M.F.; Wnek, G.E.; Chiang, L.Y.
Publisher: Mater. Res. Soc, Pittsburgh, PA, USA
Publication Date: 1996 Country of Publication: USA xvi+710 pp.
Material Identity Number: XX96-02015
Conference Title: Electrical, Optical, and Magnetics Properties of Organic Solid State Materials III. Symposium
Conference Date: 27 Nov.-1 Dec. 1995 Conference Location: Boston, MA, USA
Language: English
Subfile: B

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WHITE AND UNSATURATED COLOR ORGANIC LIGHT EMITTING DIODES

A. DODABALAPUR, M. STRUKELJ, R.H. JORDAN, L. J. ROTHBERG, and T.M. MILLER
AT&T Bell Laboratories, 600 Mountain Avenue, Murray Hill - NJ 07974.

ABSTRACT

We describe the principles of operation and device characteristics of novel organic light emitting diodes in which the emission originates in a number of optically active layers. The effective emission color can be controlled by adjusting the thicknesses of the individual layers, and in this manner white and other unsaturated color LEDs with external quantum efficiency > 0.5% have been fabricated. The maximum luminance that has been achieved is ~ 4,700 Cd/m^2.

INTRODUCTION

White organic electroluminescent devices are anticipated to find use in a number of applications such as backlights. Numerous approaches, based on different physical mechanisms, have been successfully employed to realize white or near-white LEDs [1-5]. Indeed, the many approaches that have been tried are a testimony to the rich variety of device phenomena that one encounters in the field of organic electroluminescence, and also to the many degrees of freedom available in device design. Our approach to realize white and other unsaturated color LEDs is based on the well known 8-hydroxyquinoline (Alq)/triphenyl diamine (TAD) system [6]. The blue component of the spectrum is augmented by introducing a thin layer of a blue-green emitting material between the Alq and the TAD. The use of a dye-doped Alq layer in the device adds to the red component of the combined emission spectrum. In this manner, efficient (0.7% external quantum efficiency) and bright (4750 Cd/m^2) LEDs have been fabricated with emission colors that are close to white.

RESULTS and DISCUSSION

Alq/TAD LEDs in which the Alq and TAD thicknesses are typically 60 nm each have external quantum efficiencies of 0.5-0.6% with Li/Al cathodes and 0.3% with Al cathodes. The fabrication of such LEDs are described in Refs. 7 and 8. Introducing a thin layer of 2-napthyl - 4,5-bis(4-methoxyphenyl)-1,3-oxazole (NAPOXA) between the Alq and TAD causes the emission spectrum to shift to the blue (shown in Fig. 1). The external quantum efficiency, however, remains practically constant for small thicknesses (< 20 nm) of NAPOXA. The increasing blue component of the emission spectrum, as the thickness of the NAPOXA is increased, originates in the NAPOXA layer. Indeed, the electroluminescence (EL) spectrum of LEDs with a thick NAPOXA layer are almost identical to the photoluminescence spectrum of thin films of NAPOXA. Additional control studies described in Ref. 7 offer further evidence that the origin of the increased blue component is the NAPOXA and not the TAD. This is important since we wish to avoid any light emission from the TAD layer.

An examination of the fraction of the total light that is emitted from the Alq layer (as a function of the thickness of the NAPOXA layer) will help optimize the thicknesses of the

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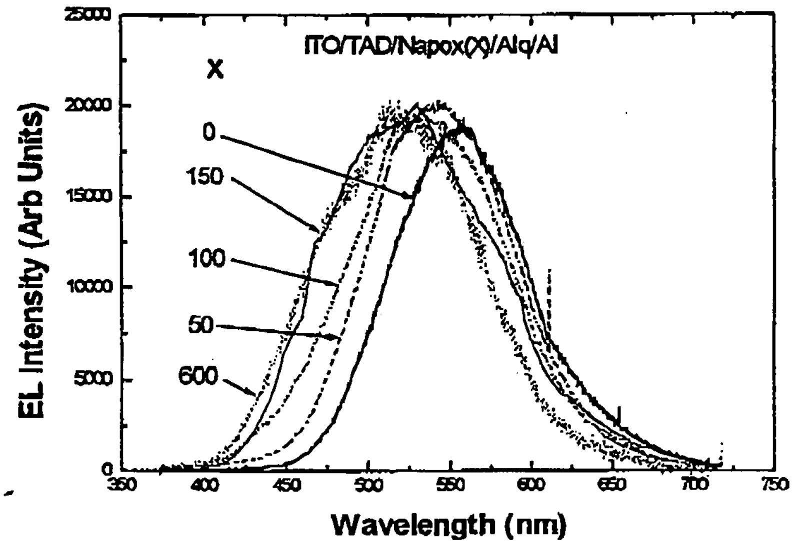

Fig. 1 Normalized electroluminescence spectra of Alq/NAPOXA/TAD LEDs as a function of NAPOXA thickness X (in Angstroms)

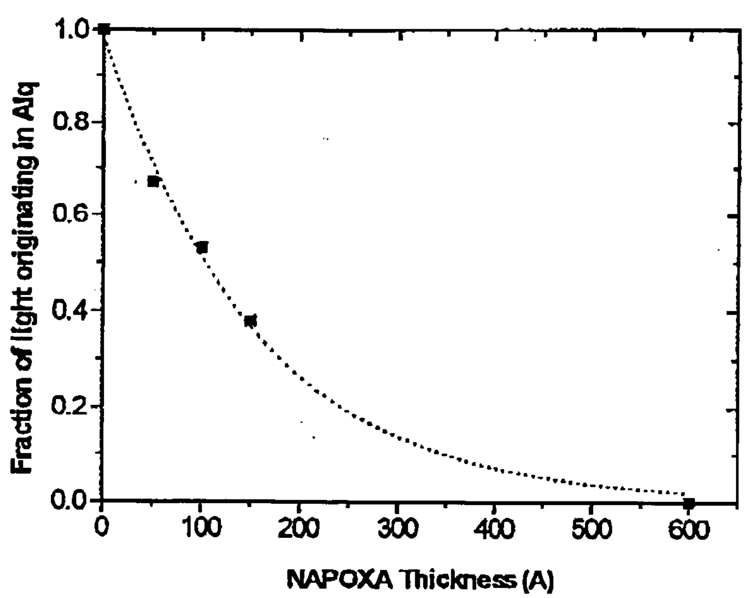

Fig. 2 Fraction of the total LED light output originating in the Alq as a function of NAPOXA thickness. Also shown is a fit to the data points.

individual layer thicknesses in the design of the white LEDs to be described below. Such estimates may be made from Fig. 1 by integrating the long wavelength portions (> 550 nm) of the curves and assuming that when the thickness of the NAPOXA is 60 nm, all the light originates in it [9]. The results of such an analysis are plotted in Fig. 2. The experimental points lie along a decaying exponential, which is not at all surprising.

It may be seen from Fig. 1 that as the thickness of the NAPOXA layer is increased, the blue component of the emission spectrum is increased and the red component reduced. It is necessary to boost the red component of the combined emission if the effective color is to approach white. The use of small amounts of fluorescent dye dopants in Alq has been shown by Tang *et al.* to alter the EL spectrum and enhance the quantum efficiency [6]. Since that report, many dyes have been successfully employed as dopants in Alq and other materials to change emission color and/or improve efficiency. The El spectrum of Alq doped with small amounts (<2%) of DCM is red shifted [6]. We introduced a thin layer of Alq doped with 0.3-0.5% DCM in our device structure designed for white light emission (shown in Fig. 3). The purpose of this layer is to boost the red component of the NAPOXA/Alq emission. It was found that if the DCM doped Alq layer was to close to the NAPOXA, the blue and green components of the combined emission spectrum are suppressed. It was therefore necessary to have an undoped Alq layer between the NAPOXA and DCM-Alq layers, as shown in Fig. 3. Adjusting the thickness of this undoped Alq layer allows us to control the combined emission spectrum. This is illustrated in Fig. 4 where the EL spectra of two devices which possess the structure shown in Fig. 3. The devices possess identical layer sequences and thicknesses with the exception of the undoped Alq layer which is 20 nm in one device and 30 nm in the other. It can be seen that the emission spectrum of the device with a 20 nm undoped Alq layer has a peak near 575 nm whereas the device with a 30 nm thick Alq layer has a broad emission spectrum with significant blue, green, and red components. The device with a 30 nm thick Alq layer has CIE coordinates of (0.31,0.41), which are the closest to white (0.33,0.33) that we have achieved. Subtracting a small amount of green from the spectrum will move the CIE coordinates closer to those of pure white. The CIE coordinates of the device with a 20 nm undoped Alq layer are (0.41,0.49). For comparison, the CIE coordinates of Alq/TAD LEDs are (0.39,0.56) [3].

The external quantum efficiencies of LEDs with structures shown in Fig. 1 and Fig. 3 are similar (0.5-0.7% external with Li/Al contacts). The whitest LED with CIE coordinates (0.31,0.41) had an external efficiency of 0.7%, and a maximum luminance of 4750 Cd/m^2 (at 20 V and 380 mA/cm^2). The current-voltage and light output (proportional to the photocurrent output of a Si photodiode) characteristics of a Alq/NAPOXA/TAD LED are shown in Fig. 5, and are typical of many of the LEDs that were evaluated.

The white and unsaturated color LEDs we have described may find application as ultra-thin backlights [10]. The material system that we developed to get white LEDs (with multiple emitting layers) will also be very useful in a number of microcavity LED applications which we have proposed. These include a multimode microcavity enhanced three-color backlight , and a patterned single mode microcavity LED- based architecture to achieve full color displays [11].

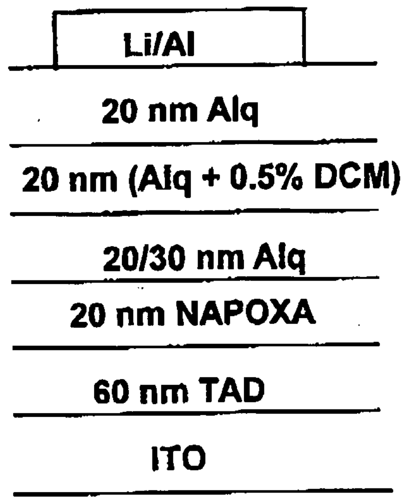

Fig. 3 Layer structure of the white/unsaturated color LEDs. Most of the blue light originates in the NAPOXA. The NAPOXA and Alq layer adjacent to the NAPOXA contribute much of the green component and the DCM doped Alq together with the undoped Alq is the source of red part of the combined emission spectrum.

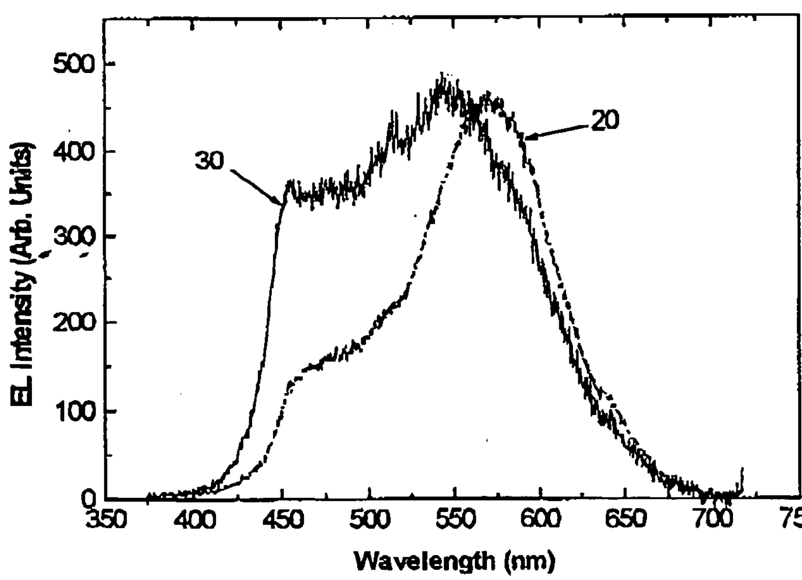

Fig. 4 Electroluminescence spectra of two LEDs with a layer structure shown in Fig. 3 with different undoped Alq thicknesses (20 nm and 30 nm).

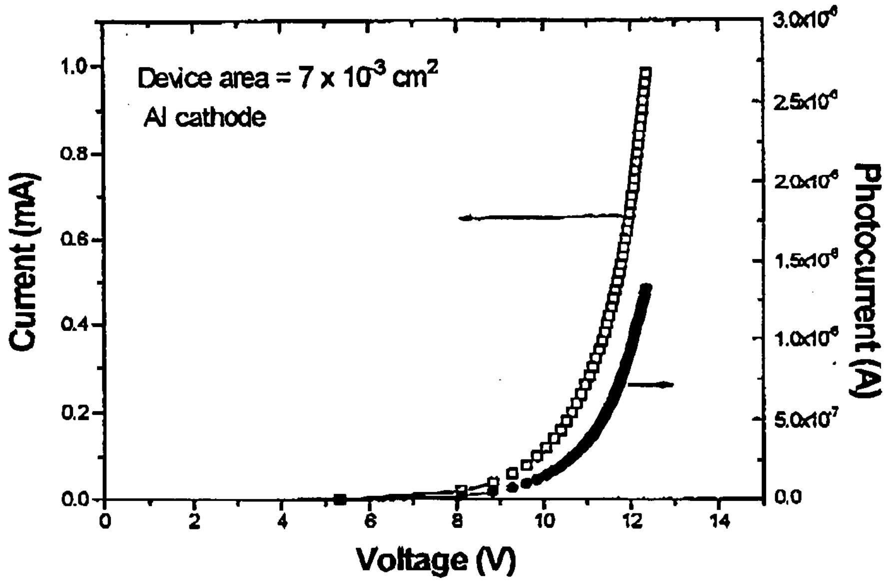

Fig. 5 Typical current-voltage characteristics of Alq/NAPOXA/TAD LEDs. Also shown is the light output as measured by the photocurrent from a Si photodiode placed very close to the LED.

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9. Integrating the short wavelength portions of the spectra also yielded similar results.
10. The luminous efficiency (0.5 lm/W) is still more than an order of magnitude lower than those of fluorescent backlights.
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Fig. 3